EVALUATION OF ENVIRONMENTAL DATA
PERTAINING TO THE GREEN BAY LEVEE.

By: Richard E. Sparks

1989

Punch and place in brown binder

ILLINOIS NATURAL HISTORY SURVEY

~~Natural Resources Building~~
~~Urbana, Illinois 61801~~
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1989

Telephone: 333-6880
Area Code 217

GEORGE SPRUGEL, JR., Chief

Miss. R. - Pool 19
Annoncing
Risk Assessment

27 January 1977

Fringe, ... clams
Flooding

Mr. Frank Collins, Chief
Environmental Resources Section
Corps of Engineers, Rock Island
Clock Tower Building
Rock Island, Illinois 61201

Dear Mr. Collins:

I am enclosing my evaluation of the environmental data relating to the Green Bay Levee. I am recommending 200-year flood protection for the entire District, with material for improvement of the main stem levee to be obtained by dredging from the main channel adjacent to the levee. I believe the dredging should be subject to certain restrictions, which I have discussed in the report. I also feel very strongly that a comprehensive management plan should be developed for Pool 19, and perhaps for the entire Upper Mississippi River.

The enclosed report is the original, and I would be very grateful if you would send us one Xerox copy. We have no copy machine at our laboratory, and I did not want to waste time by sending the original to our main office in Champaign-Urbana. We have one carbon copy of the text, but no copies of some of the original figures. Please let me know if I can furnish you with any additional information.

Sincerely yours,

Rip Sparks

Richard E. Sparks

Enclosure
RES:hh

Econ. anal. p 2-3
Consumption by ducks p. 7
Consumption by ducks p. 25, 26 (Table)

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prepared January 31, 1977

by Richard E. Sparks
River Research Laboratory
Illinois Natural History Survey
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I. BIOLOGICAL SIGNIFICANCE OF POOL 19

Historical Changes in the River and the Benthos

The reach of the Mississippi River which lies between Lock and Dam No. 18 at Burlington, Iowa and Lock and Dam No. 19 at Keokuk, Iowa is much different today than it was prior to the turn of the century. The upstream portion in the vicinity of the Green Bay Levee District was once flanked by bottomland forests, lakes, side channels, and sloughs. The downstream portion at Keokuk, Iowa was known as the Des Moines Rapids. The organisms found in the upstream portion ranged from types which were adapted to living in shallow backwaters with little or no current to types which prefer main channel habitat and current. Organisms which lived in the rapids at Keokuk, such as the net-spinning caddis flies, were adapted to life on rocky substrates and swift water. These same species can be found today on the underwater portions of Lock and Dam 19 and on the submerged rubble immediately below the dam (Fremling, 1960: 867). In the 1800's some of the backwaters and bottomland areas were leveed and drained, and a longitudinal dam with three locks was built through the Des Moines Rapids (U.S. Army Corps of Engineers, 1975: 9; U.S. Army Corps of Engineers, 1972). Between 1905 and 1913 a hydroelectric plant with a dam, powerhouse, lock and dry dock were constructed at Keokuk by the Mississippi River Power Company, now the Union Electric Power Company.

With completion of the dam in 1913 the surface acreage of Keokuk Pool during low water stages increased from 90 square kilometers (35 square miles) to 150 square kilometers (58 square miles) (Carlander, 1954: 21). Broad mud flats were flooded which provided suitable habitat for species such as burrowing mayflies and fingernail clams. In addition, organic matter and fine sediment were deposited upstream from the dam. Between 1913 and 1930, populations of organisms adapted to living in mud bottoms probably increased, while organisms adapted to living in clean sand or rubble bottoms and swift current diminished. Ellis (1931: 8) reported that the once abundant beds of freshwater mussels which were worked commercially in the region covered by Lake Keokuk disappeared in the period following construction of the dam. There appears to have been little change in the species composition of the benthic community from Ellis's study in 1930 to more recent times (Carlson, 1968: 166-168; Gale, 1969: 65-66; Illinois Natural History Survey, 1973-1977, unpublished data). The benthic community in Pool 19 corresponds closely to that which Gersbacher (1937) described as a Hexagenia-Musculium-Viviparus climax community characteristic of large rivers. Detritus seems to form the basis of the food chain of this benthic community, and the community is probably dependent on the importation of organic material from upstream marshes, tributaries, and perhaps manmade sources (Carlson, 1968: 1967).

Populations of benthic organisms in Keokuk Pool are among the densest found in any body of water in the world. We have found that the average biomass in Keokuk Pool would be on the order of 1,000 kilograms/hectare (892 pounds/acre). At our best station (mile 376.5) we found over 8,000 kilograms/hectare (7,137 pounds/acre) in August, 1973. Gale (1969: 35)

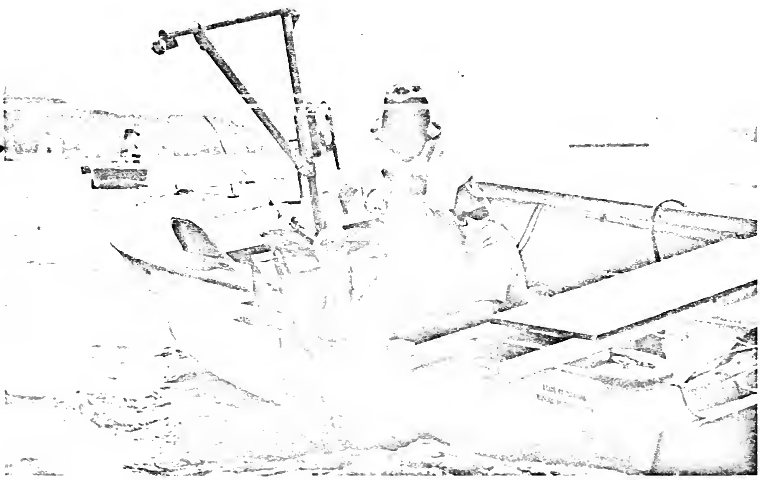
found that the mollusk biomass (which formed more than 90% of the total biomass) averaged 1,842 kilograms/hectare (1,643 pounds/acre) in the lower third of Pool 19, 1,521 kilograms/hectare (1,357 pounds/acre) in the middle third, and 5,308 kilograms/hectare (4,736 pounds/acre) in the upper third for a grand average of 2,777 kilograms/hectare (2,478 pounds/acre) in the entire Pool. The differences between Gale's findings and ours could be due to a real decline, or more likely, due to the fact that Gale reported the biomass in September, when the biomass is at a peak, and we are reporting a seasonal average.

Whether one uses Gale's figures or ours, the biomass at Keokuk Pool is exceptionally high. Hayes (1957) reported biomass data from 251 lakes and found that most contain less than 100 kilograms/hectare (89 pounds/acre) of bottom fauna. Moyle (1961) reported the results of several studies on ponds, lakes and rivers in which most contained less than 560 kilograms/hectare (500 pounds/acre). Moyle (1961) reported that the Mississippi River and slow streams in New York sometimes had standing crops exceeding 1,000 kilograms/hectare (892 pounds/acre) with a maximum of 3,982 kilograms/hectare (3,553 pounds/acre). Richardson (1921) reported up to 5,807 kilograms/hectare (5,181 pounds/acre) in the Illinois River prior to heavy pollution loads, but many of his estimates were less than 500 kilograms/hectare (446 pounds/acre). By contrast, the Missouri River has a very low biomass. Berner (1951) and Morris et al. (1968) reported less than 1 kilogram/hectare (0.89 pounds/acre). Grover (1969) reported 11.3 kilograms/hectare (10.1 pounds/acre) in Lake Sharpe on the Missouri. The benthic food resource is the primary reason for the heavy duck utilization and high fish production of Pool 19.

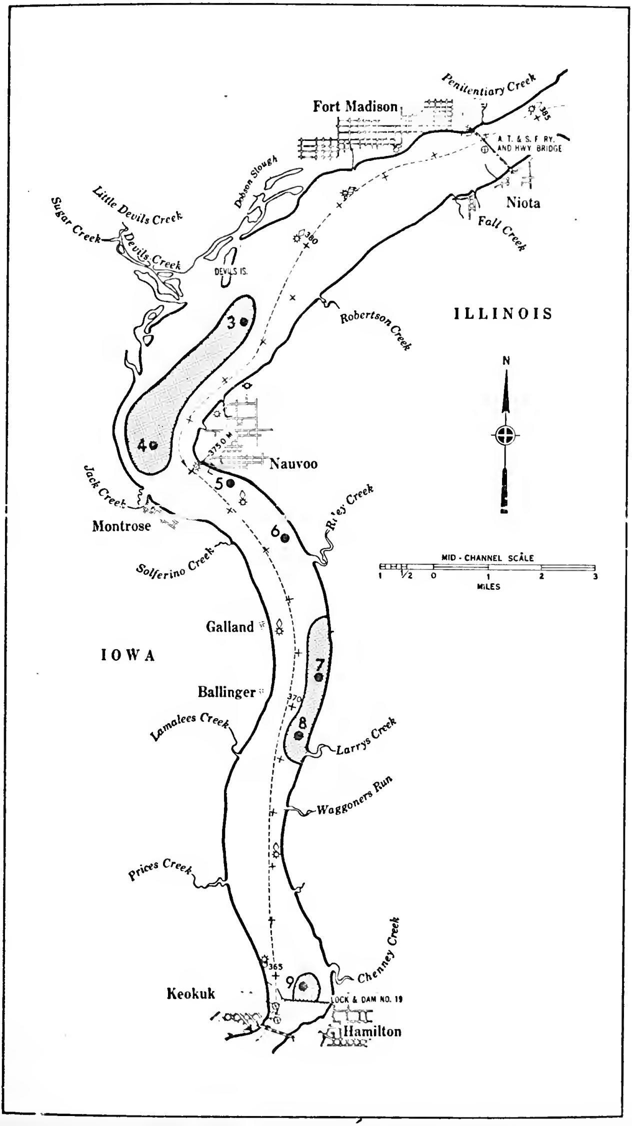
Dr. Frank C. Bellrose and Mr. Robert Crompton of the Illinois Natural History Survey have conducted weekly aerial censuses of waterfowl populations in the Illinois River valley and the portion of the Mississippi valley which includes Keokuk Pool since 1946. Since 1973, the author and Mr. Carl M. Thompson have engaged in a cooperative study with Dr. Bellrose and Mr. Crompton of the relationship between diving duck populations and food resources in the Keokuk Pool between Lock and Dam 19 and the Fort Madison bridge. Figure 1 shows the equipment used in sampling the benthic organisms and Figure 2 shows the benthic sampling stations and diving duck concentration areas. This research has received major support from the Illinois Department of Conservation and the Northern Prairie Wildlife Research Station of the U.S. Fish and Wildlife Service. At various times, we have been assisted by investigators from the Illinois State Water Survey, the University of Illinois, and Western Illinois University.

The aerial censuses have shown that Pool 19 receives about 20 million diving duck-days of use per year. The Pool has therefore been characterized as the most important inland body of water for diving ducks in North America (Trauger and Serie, 1974: 71). Utilization of the Pool by diving ducks is directly attributable to the rich abundance of benthic food organisms, particularly one species of fingernail clam, *Musculium transversum*. Thompson (1969: 73) found the diet by volume of lesser scaups (*Aythya affinis*), ring-necked ducks (*Aythya collaris*), canvasbacks (*Aythya valisineria*), common goldeneyes (*Bucephala clangula*), and American coots (*Fulica americana*) to consist of 85-95% fingernail clams and estimated a fall harvest by migrating waterfowl of about 2,500 tons (2,268,000 kilograms) of these sphaeriids

Figure 1. Ponar dredge and special washing sieve used by Illinois Natural History Survey in sampling benthic organisms in Pool 19. An Illinois Water Survey boat and crew are visible in the background, measuring benthic oxygen demand.



rafts of diving ducks have concentrated in 1973-1977 are stippled. Benthic sampling stations are numbered. Stations 5 and 6 were purposely located in an area little used by diving ducks. Diving duck concentration areas in the text are referred to as area 3-4, area 7-8, and area 9.



from Keokuk Pool. In November, 1975, we found that fingernail clams (two species, Musculium transversum and Sphaerium striatinum) comprised 76.4% of the total organic contents in a food habits analysis of the gizzards of 49 lesser scaups.

Nutritional value of fingernail clams for waterfowl

Fingernail clams furnish a nutritious food for waterfowl. We have found that commercial poultry food contains 16.50% crude protein. Musculium transversum contains 13.25% crude protein, and another species of clam, Corbicula manilensis, contains only 3.15% (Thompson and Sparks, in press). Most of the literature available on the food requirements of waterfowl deals with the requirements of confined ducklings and breeding adults. Holm and Scott (1954: 186) reported that the protein requirements of young wild ducklings of several different species was found to be no greater than 19%, with an 8% level of animal protein producing satisfactory growth. A breeder diet containing 18.6% protein gave satisfactory egg production and hatchability. Therefore fingernail clams supply 69.7% and 165.6% of the respective protein levels required for maximum and satisfactory growth of wild ducklings. The clams provide 71.2% of the satisfactory protein levels for breeding adults.

Increasing utilization of Pool 19 by ducks attributable to declining food resources elsewhere

Utilization of Keokuk Pool by diving ducks and coots has increased since the 1940's. Use of the Pool by lesser scaup ducks (Figure 3) has increased slightly since the 1940's and 1950's, while use by the American coot (Figure 4) and the canvasback duck (Figure 5) has increased explosively. Part of this increase is attributable to declining habitat and food resources along the migration routes and in the wintering grounds. For example, the

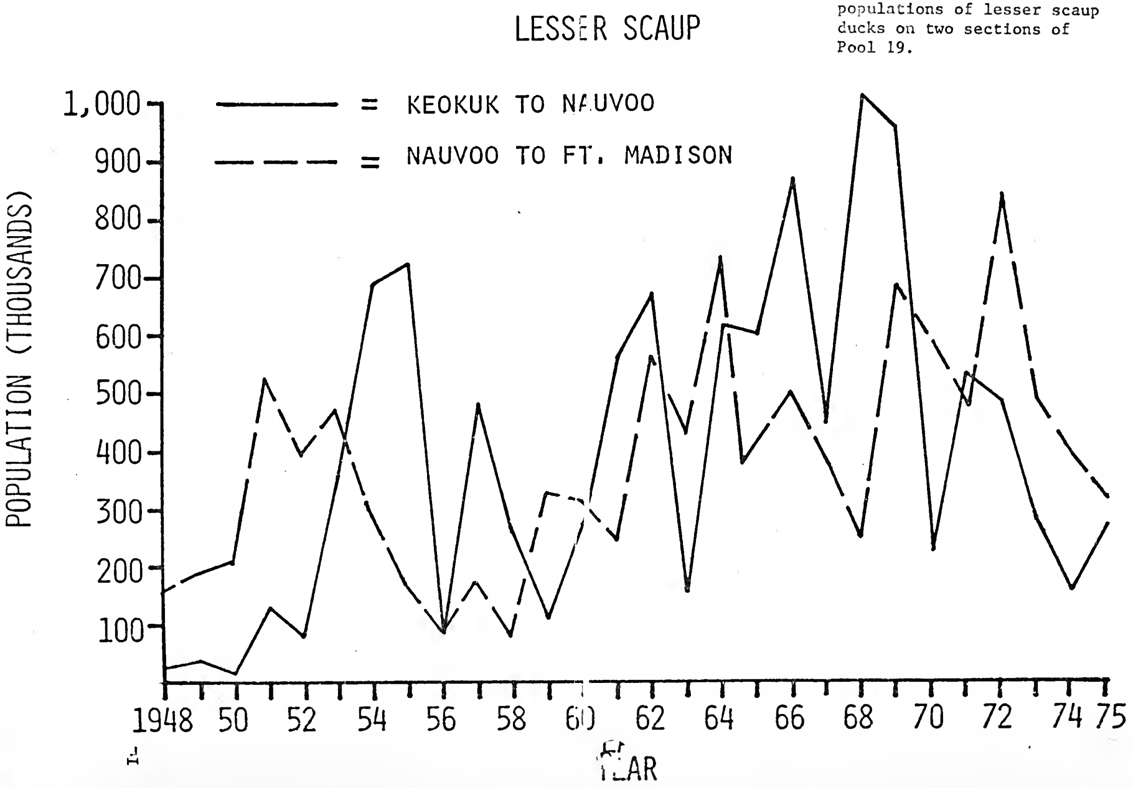
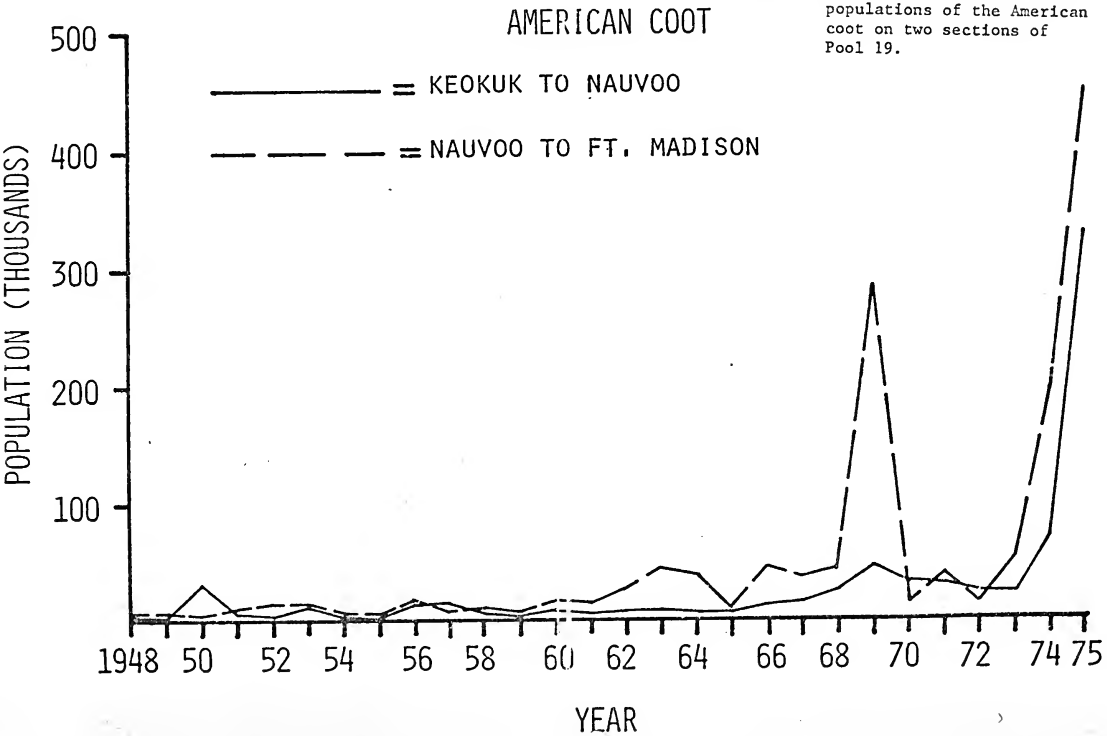


Figure 3. Historical changes in the populations of lesser scaup ducks on two sections of Pool 19.

Figure 4. Historical changes in the populations of the American coot on two sections of Pool 19.



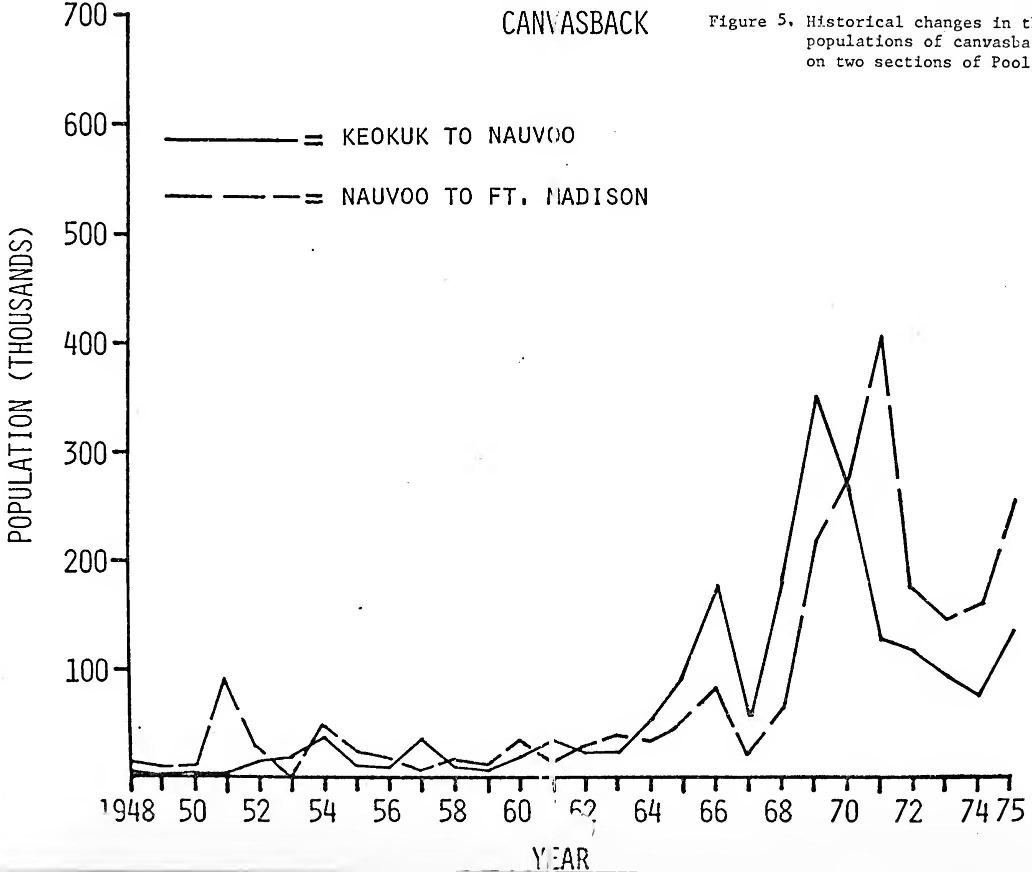
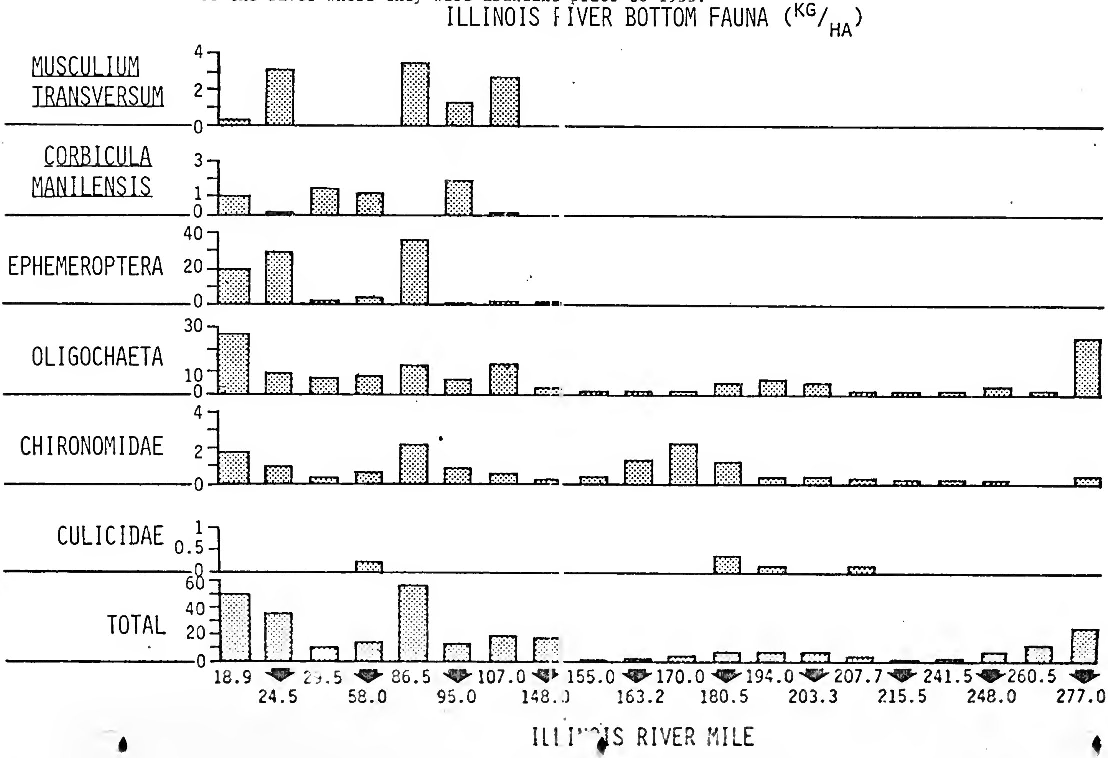


Figure 5. Historical changes in the populations of canvasbacks on two sections of Pool 19.

canvasback formerly fed primarily on plant food (Bellrose, 1976: 312-313). In fact, the scientific name for the canvasback duck, <u>Aythya valisineria</u>, is derived from the scientific name for wild celery, <u>Vallisineria americana</u>, which was a favored food of the canvasback until it began to disappear in the Great Lakes states and Chesapeake Bay (Bellrose, 1976: 312-313).

The Illinois River once formed a major arm of the Mississippi Flyway, and canvasback ducks were once attracted to beds of wild celery which existed in Peoria Lake (a main stem lake in the Illinois River) and to beds of fingernail clams which existed in the middle section of the Illinois River. In the 1950's the vegetation and the fingernail clams disappeared from a 180-mile section of the Illinois River. Figure 6 shows that as recently as 1975 the biomass of <u>Musculium transversum</u> in the lower part of the Illinois River was very low (less than 4 kilograms/hectare, 3.6 pounds/acre), and there were no fingernail clams at all above river mile 148. Figure 7 shows what happened to the diving duck populations on the Illinois River following the die-off of fingernail clams in 1955. The number of lesser scaup and other diving ducks using the Illinois valley declined drastically in 1955 and has never recovered. In 1972, Hurricane Agnes caused flooding along the Eastern seaboard. The sediment which was washed into the coastal marshes and estuaries reduced some of the remaining beds of vegetation, and the fresh water diluted the salt water to such an extent in many areas that benthic animal populations were severely reduced. The hurricane was a natural event, but the amount of flooding and sedimentation which resulted was probably increased as the result of man's use of the land in the affected basins.

Figure 6. Results of a fall, 1975 survey of benthic populations in the Illinois River. The biomass of fingernail clams (Musculium transversum) and mayflies (Ephemeroptera) was extremely low in the downstream sections of the river, and these organisms were absent from the middle section of the river where they were abundant prior to 1955.



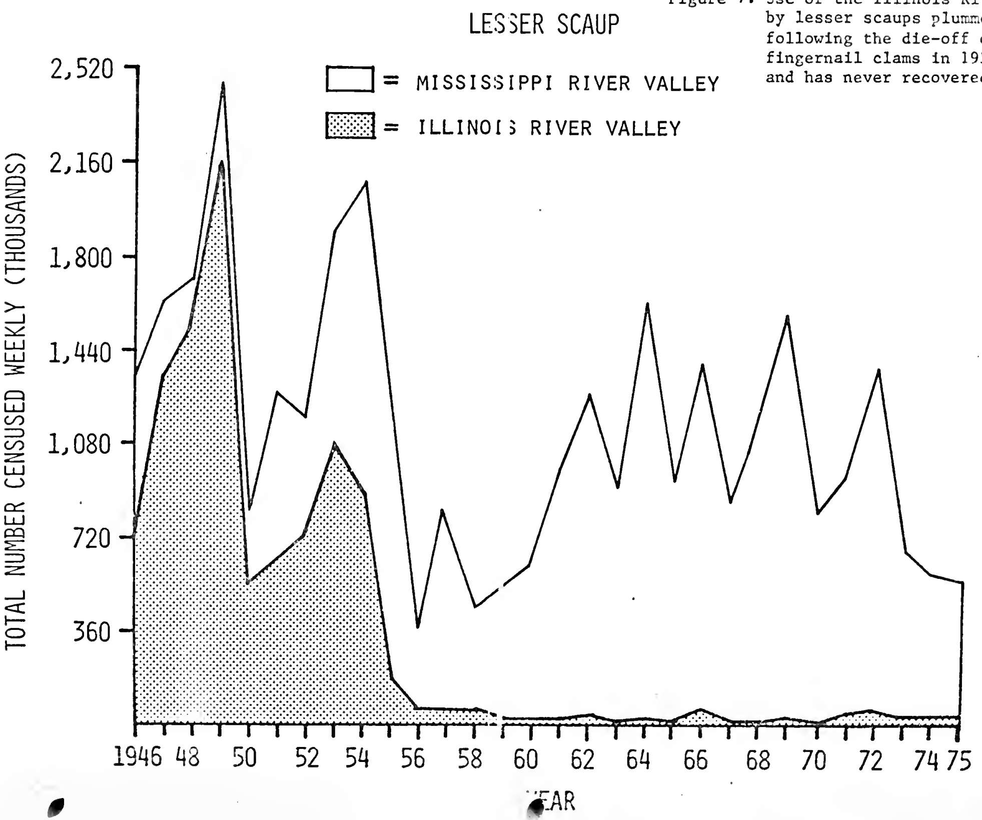


Figure 7. Use of the Illinois River by lesser scaups plummeted following the die-off of fingernail clams in 1955 and has never recovered.

The die-off of plant and animal food in the Illinois River in the 1950's, and the resulting calamitous decline in diving duck utilization of the Illinois valley, illustrate how dependent the ducks are on food resources along the migration route.

Use of the project area by diving ducks

Tables 1-4 show the diving duck utilization of various sub-areas within Pool 19, including the area between Dallas City and Burlington, which includes the proposed dredging site. The diving ducks use the Dallas City-Burlington area to a much greater degree in the spring than in the fall. Use of the area by lesser scaup ducks ranged between 0.0 and 0.5% of total Pool usage in the fall (Table 1), and between 2.2 and 41.6% in the spring (Table 2). Usage by canvasbacks ranged from 0.0 to 1.5% in the fall (Table 3) and 3.0 to 10.2% in the spring (Table 4).

Critical periods for ducks and food organisms

Figure 8 shows that the critical period of the year for both diving ducks and the food organisms occurs in the spring, when the populations of food organisms are at low ebb and the ducks must find food so they can arrive on the breeding grounds in good condition.

Table 1

Duck-Days of Use of Four Sections of Pool 19 by Lesser Scaup Ducks During the Fall Migration*

Year	Keokuk-Nauvoo	Nauvoo-Ft. Madison	Ft. Madison-Dallas City	Dallas City-Burlington	Total
1959	799,000 (22.05)	2,238,400 (61.78)	585,840 (16.17)	0 (0)	3,623,240
1960	1,533,550 (40.57)	2,136,950 (56.53)	109,900 (2.91)	0 (0)	3,780,400
1961	3,907,400 (60.41)	1,790,270 (27.68)	770,440 (11.91)	0 (0)	6,468,110
1962	4,798,300 (52.42)	4,083,000 (44.61)	270,700 (2.96)	1,400 (0.01)	9,153,400
1967**	3,036,400 (48.08)	2,272,645 (35.98)	1,006,800 (15.94)	0 (0)	6,315,845
1974	1,107,120 (27.68)	2,833,355 (70.83)	41,021 (1.03)	18,616 (0.47)	4,000,112
1976	705,805 (31.13)	1,492,500 (65.82)	57,755 (2.55)	11,500 (0.51)	2,267,560

*The percentage of total use of the entire Pool is given in parentheses. Duck-days are computed by multiplying the population observed during an aerial census by the number of days (usually 7 days) since the previous census.

**Census period did not encompass full migration period, so values for this year underestimate the actual number of duck-days of use.

Table 2

Duck-Days of Use of Four Sections of Pool 19 by Lesser Scaup Ducks During the Spring Migration*

Year	Keokuk-Nauvoo	Nauvoo-Ft. Madison	Ft. Madison-Dallas City	Dallas City-Burlington	Total
1959**	71,100 (5.53)	496,730 (38.60)	599,970 (46.42)	119,050 (9.25)	1,286,850
1960	49,760 (17.07)	83,075 (28.50)	37,390 (12.83)	121,260 (41.60)	291,485
1961**	2,106,780 (35.95)	2,247,400 (38.35)	1,167,600 (19.92)	338,600 (5.78)	5,860,380
1962	988,100 (19.51)	1,923,600 (37.99)	1,191,575 (23.53)	960,100 (18.96)	5,063,375
1967**	1,773,500 (21.63)	2,771,000 (33.79)	2,854,700 (34.81)	800,550 (9.76)	8,199,750
1974**	525,725 (21.63)	1,679,000 (69.08)	172,400 (7.09)	53,500 (2.20)	2,430,625
1976**	552,350 (55.07)	364,000 (36.29)	54,900 (5.47)	31,715 (3.16)	1,002,965

*The percentage of total use of the entire Pool is given in parentheses. Duck-days are computed by multiplying the population observed during an aerial census by the number of days (usually 7 days) since the previous census.

**Census period did not encompass full migration period, so values for this year underestimate the actual number of duck-days of use.

Table 3

Duck-Days of Use of Four Sections of Pool 19 by Canvasback Ducks During the Fall Migration*

Year	Keokuk-Nauvoo	Nauvoo-Ft. Madison	Ft. Madison-Dallas City	Dallas City-Burlington	Total
1959	27,810 (19.35)	79,490 (55.32)	36,400 (25.33)	0 (0)	143,700
1967**	509,330 (39.41)	174,765 (13.52)	606,900 (46.96)	1,500 (0.12)	1,292,495
1976	272,290 (29.28)	548,490 (58.99)	94,715 (10.19)	14,300 (1.54)	929,795

*The percentage of total use of the entire Pool is given in parentheses. Duck-days are computed by multiplying the population observed during an aerial census by the number of days (usually 7 days) since the previous census.

**Census period did not encompass full migration period, so values for this year underestimate the actual number of duck-days of use.

Table [illegible]

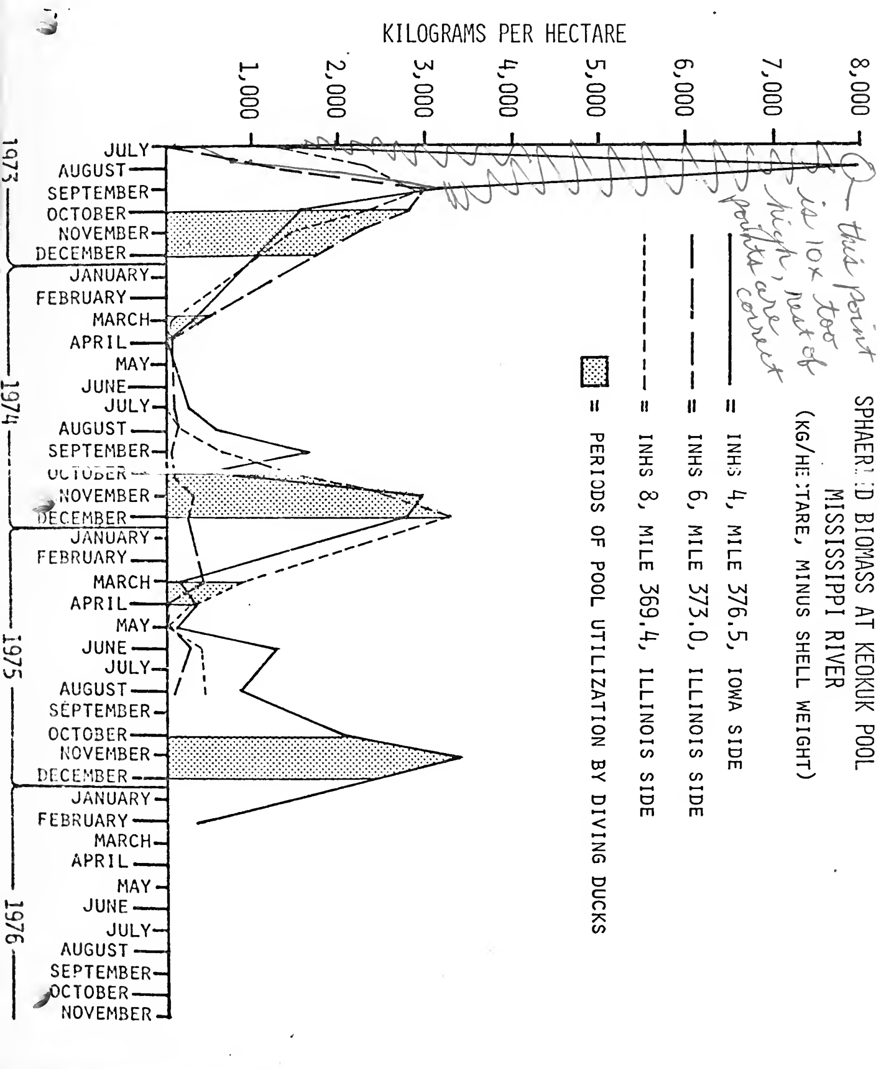
Duck-Days of Use of Four Sections of Pool 19 by Canvasback Ducks During the Spring Migration*

Year	Keokuk-Nauvoo	Nauvoo-Ft. Madison	Ft. Madison-Dallas City	Dallas City-Burlington	Total
1959	3,360 (4.47)	22,750 (30.29)	41,300 (54.99)	7,700 (10.25)	75,110
1967**	79,500 (6.30)	533,450 (42.26)	602,680 (47.74)	46,730 (3.70)	1,262,360
1976**	1,050,470 (41.38)	1,112,350 (43.82)	299,100 (11.78)	76,725 (3.02)	2,538,645

*The percentage of total use of the entire Pool is given in parentheses. Duck-days are computed by multiplying the population observed during an aerial census by the number of days (usually 7 days) since the previous census.

**Census period did not encompass full migration period, so values for this year underestimate the actual number of duck-days of use.

Figure 8. The critical period for both the diving ducks and the fingernail clams occurs in the spring when the clam populations are at low ebb and the ducks must find food to sustain them on their flight to the breeding grounds.



Effects on diving ducks of the 1976 decrease in benthic populations in Pool 19

In the fall and winter of 1976-77, there has been an alarming decrease in the biomass of benthic organisms in Keokuk Pool (Figure 9). The decrease in fingernail clam biomass has been even more alarming. In comparison to the fall of 1975, the fingernail clam biomass at Station 4 (Figure 2) has been reduced by 90-95%. There are few juvenile clams, indicating a lack of reproduction, and the adults are much smaller than the 1975 adults, indicating retarded growth. The reduced amount of food already may have had an impact on diving duck use of Keokuk Pool. Table 5 shows a 49% decrease in the peak population of canvasback ducks on Pool 19 between 1975 and 1976. The decline cannot be attributed to a decline in the population produced on the breeding grounds, which amounted to only a 3% decrease. A 20% decrease in the peak population occurred on Pools 7, 8, and 9, of the Mississippi River and a 30% decrease occurred in the Lake Ontario area. Lesser scaup populations showed a 16% decrease on Keokuk Pool, which can be explained by a 14% decrease on the breeding grounds. The reason the lesser scaup may not have been affected to the same extent as the canvasback by the lack of food is that the peak population of scaup arrive on the feeding areas approximately two weeks ahead of the peak population of canvasbacks (Figures 10 and 11). The lesser scaup may have consumed what food was available prior to the arrival of the peak population of canvasbacks.

Figure 9. Biomass (kg/hectare) of benthos in Keokuk Pool, Mississippi River (mi. 376.5), 1973-1976. The lower line (dashed) represents the standing crop of fingernail clams (Musculium transversum). Mollusc weights are exclusive of shells.

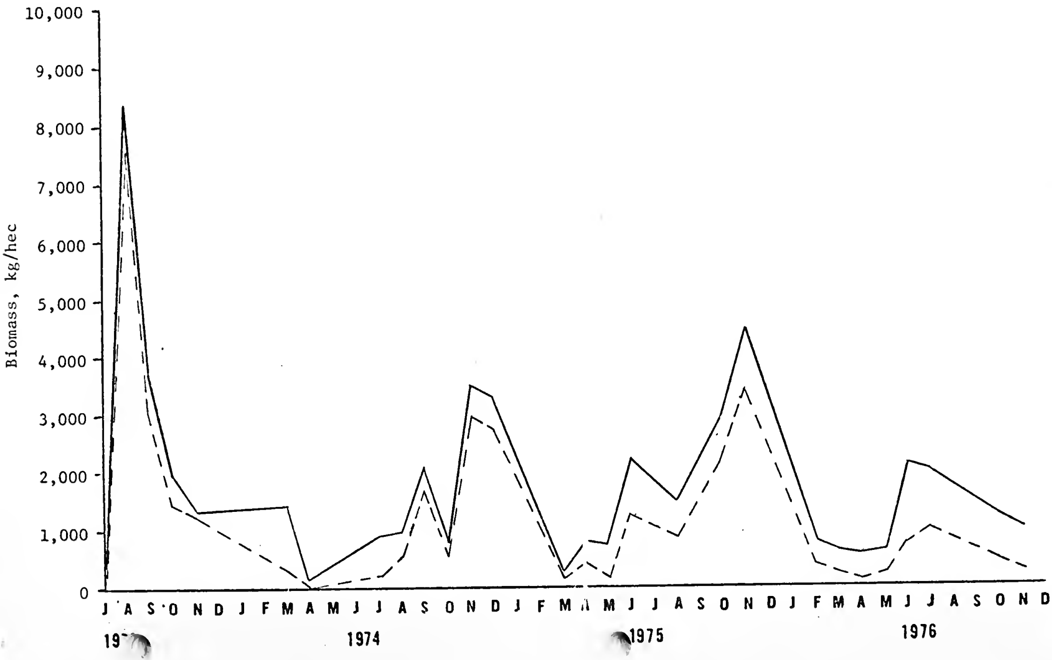


Table 5

Peak Populations of Lesser Scaup and Canvasback Ducks in Various Portions of the Mississippi and Atlantic Flyways in 1975 and 1976*

	Lesser Scaup	Canvasbacks
	Breeding Grounds	
1975	7,846,000	706,000
1976	6,720,000 (14% decrease)	682,000 (3% decrease)
	Mississippi River Pools 7, 8, 9	
1974		83,900
1975		148,225 (77% increase)
1976		118,300 (20% decrease)
	Lake Ontario Area	
1975		100,731
1976		70,165 (30% decrease)
	Mississippi River Pool 19	
1975	147,400	105,175
1976	123,150 (16% decrease)	53,600 (49% decrease)

*Pool 19 data supplied by Dr. Frank C. Bellrose, Illinois Natural History Survey. All other data supplied by Dr. David Trauger, Northern Prairie Wildlife Research Station, U.S. Fish and Wildlife Service, Jamestown, North Dakota.

Figure 10. The peak population of lesser scaup ducks arrived approximately two weeks before the peak population of canvasbacks in the fall of 1975.

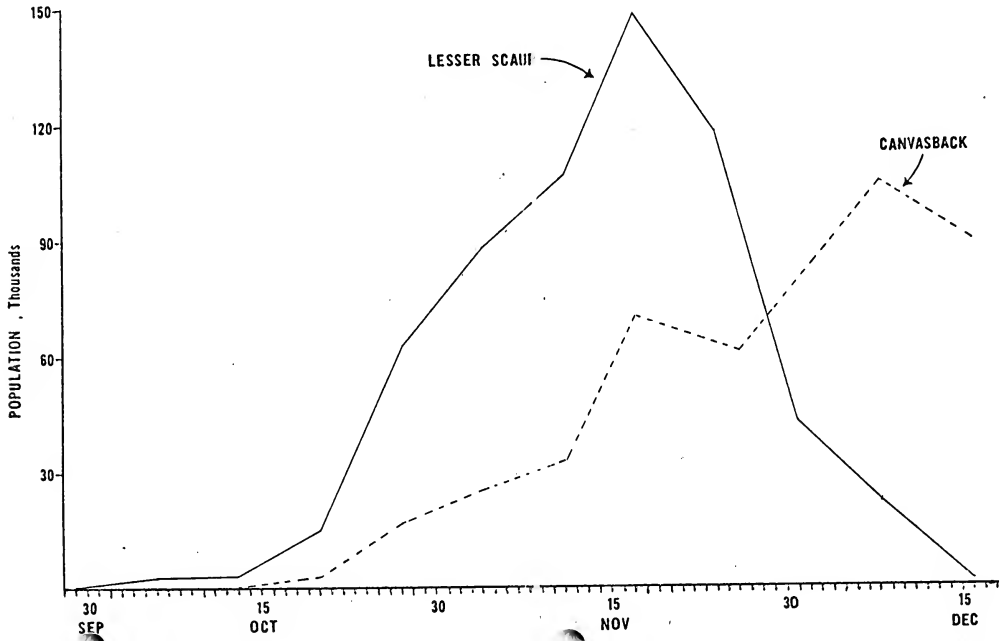


Figure 11. The peak population of lesser scaup ducks arrived approximately two weeks before the peak population of canvasbacks in the fall of 1976.

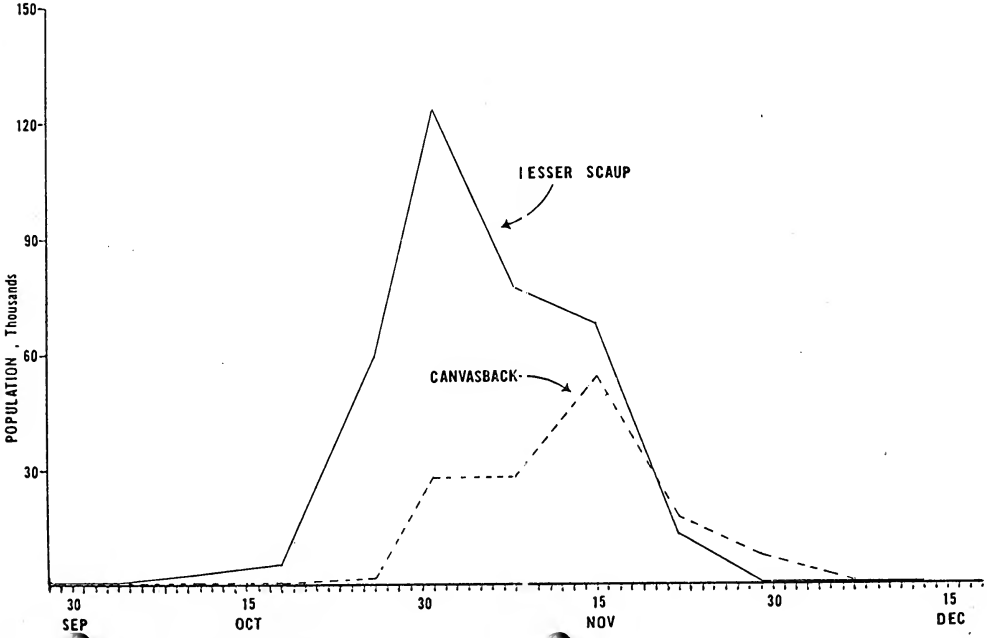


Table 6 shows that lesser scaup and canvasback ducks were potentially capable of consuming most of the fingernail clam biomass in 1967 and 1973, and all of the biomass in 1976. The calculation is based on the assumption that the birds consume 0.22874 kilograms of clams per duck per day (0.5044 pounds), an amount actually consumed by ducks in cool water in the fall when they are free to dive, rather than being penned in cages (Thompson, 1969). The fact that the ducks could have consumed more than 100% of the clams that were available indicates that they were not meeting their food requirements in 1976. In examining Table 6 one must remember that ducks are not the only predators of fingernail clams. Leeches and fish, which are the subject of the next section, also feed on the fingernail clam, so it appears that the fingernail clams in Pool 19 are being fully exploited (Gale, 1973: 184-185). There evidently is not an excess of benthic food organisms in Keokuk Pool.

There are various ecological and physiological reasons why the ducks actually harvest much less than the amount of food shown to be available in dredge hauls. A diving duck must be able to obtain enough food on each dive to repay the energy cost in diving and foraging on the bottom. The greater the depth of water, and the greater the depth of food in the mud, the greater the energy cost. Figure 12 shows the vertical distribution of fingernail clams in the mud at various times of year. In April and May the fingernail clams begin moving upward to the surface of the mud, where they become increasingly vulnerable to predation by diving ducks. In October through December, they begin migrating down into the mud, where they are less subject to predation by ducks. It is fortunate that the clams exhibit this behavior, so that a residual population is available to

Table 6

Potential Harvest of Fingernail Clam Biomass
By Lesser Scaup and Canvasback Ducks at a Major Feeding Area on Keokuk Pool, Mile 376.0 - 381.5 (Illinois Natural History Survey Study Area 3-4*)

Year	Lesser Scaup, Canvasback Duck-Days At Area 3-4	Fingernail Clam Biomass Prior to Duck Arrival Kg./ Hectare	Total Kg. In Area 3-4***	Estimated Clam Consumption, Kg.****	Potential Harvest, %
1967	2,447,410	757**	614,306	559,821	91.13
1973	4,244,050	1,600	1,298,400	970,784	74.77
1976	2,040,990	450	365,175	466,856	127.84

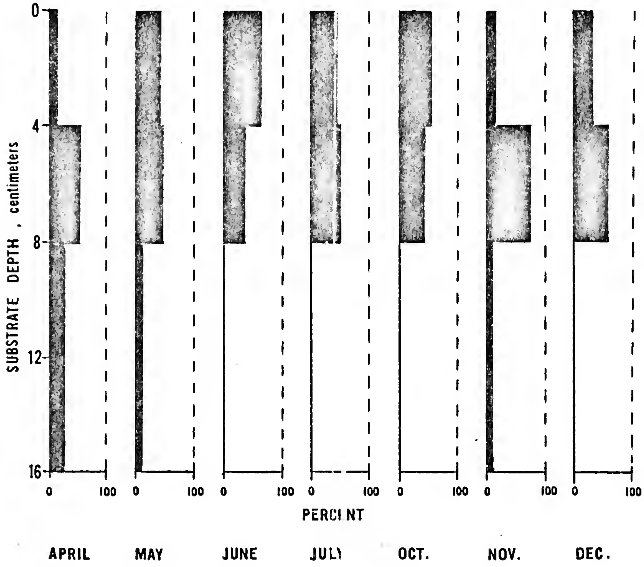
*A 811.5-hectare area between Nauvoo and Fort Madison where large rafts of lesser scaup and canvasbacks have historically concentrated.

**Gale (1969).

***Kg./hec. x 811.5 hectares.

****Duck-days x .22874 kg./duck/day (.22874 kg./duck/day from Thompson, 1969).

Figure 12. Vertical distribution of fingernail clams in the substrate at Keokuk Pool, Mississippi River (Mile No. 376.5) in 1976.



repopulate the area during the summer and fall. The population density of the food organisms, the size of the individual organisms, and the energy content of the organism are also extremely important to the overall energy balance of the diving duck.

If the ducks are obtaining less food energy than they are expending in foraging, they will presumably try to find other feeding areas, which is probably what happened to the canvasbacks on Pool 19 in the fall of 1976 (Table 5). If food is not available in other areas (and Table 5 indicates that food may not have been available in other areas) the ducks will arrive on the wintering grounds in poor condition, and winter is a very stressful time for the birds. Dr. Frank C. Bellrose of the Natural History Survey regards the migration area as an extension of the wintering grounds. Every duck-day spent feeding on the migration route reduces pressure on the wintering grounds. If food is depleted on both the migration route and the wintering grounds, fewer ducks will arrive in the spring on the breeding grounds and the ones that remain will be in relatively poor condition.

Causes of the 1976 decline of food organisms in Pool 19

Since the water quality requirements of fingernail clams are not known, the reasons for the low population in 1976 cannot be determined. There was a severe drought in the Upper Mississippi River basin in 1976. Since the discharge of waste from industries and cities tends to remain relatively constant from year to year, while the volume of water flowing in the Mississippi was much reduced as a result of the drought, it is evident that less dilution of toxic substances may have occurred. It is also possible that less organic detritus was washing into the pool, so that

the benthic detritivores were adversely affected. It is unlikely that lack of detritus affected fingernail clams, because Gale showed that *Musculium transversum* feeds nonselectively on phytoplankton. It is clear that sediment was not responsible for the reduction of fingernail clam populations in 1976, because the Mississippi River was exceptionally free of sediment due to the lack of runoff and soil erosion. Secchi disk readings increased from 27 centimeters (11 inches) in June 1975 to 40 centimeters (16 inches) in June 1976. If nutrients such as nitrates and phosphates were in greater concentrations in 1976 as a result of the low dilution, and the water was also clearer as a result of decreased sediment, the phytoplankton populations would be expected to increase, thus providing more food for the fingernail clams.

Fish

The benthic organisms in Keokuk Pool also supply food for fish. Jude (1968) and Ranthum (1969) reported that channel catfish (*Ictalurus punctatus*), carp (*Cyprinus carpio*), bullheads (*Ictalurus* spp.), and gizzard shad (*Dorosoma cepedianum*), were major predators on fingernail clams in Pool 19. Hoopes (1960: 32) reported that:

> during 1958 mayfly naiads, *Hexagenia* spp., comprised over 50 percent by volume of the food of channel catfish (*Ictalurus punctatus*), freshwater drum (*Aplodinotus grunniens*), mooneyes (*Hiodon tergisus*), goldeyes (*Hiodon alosoides*), and white bass (*Morone chrysops*), and over 40 percent of the food of paddlefish (*Polyodon spathula*) and white crappies (*Pomoxis annularis*). These naiads were also eaten by shovelnose sturgeon (*Scaphirhynchus platorynchus*). Larval caddis flies, *Potamyia flava*, comprised over 60 percent of the food of the shovelnose sturgeon and between 10 and 20 percent of the food of mooneyes, goldeyes, and white crappies.

Surprisingly, even species such as the gizzard shad, which have been shown to feed on zooplankton in other areas, feed primarily on fingernail clams (Jude, 1973: 380-381) in Keokuk Pool.

Fingernail clams are a nutritious food for fish. Nail (1971) found that channel catfish require a diet containing 25.3% protein for optimum growth. Fingernail clams supply 52.4% of the dietary protein needed by channel catfish, whereas another species of clam, Corbicula manilensis, supplies only 12.5% (Thompson and Sparks, in press). Jude (1973: 382) found that the coefficient of condition of gizzard shad in Pool 19 exceeded 11 comparable values reported in Jester and Jensen (1972: 33) and that the gizzard shad in deeper waters fed to a greater extent on fingernail clams and were significantly heavier at a given length than fish from shallow waters (Jude, 1973: 381). Gizzard shad serve as forage for game fish (Ranthum, 1969) and play the role of a buffer species. Ranthum (1969) found that the availability of large numbers of shad may serve to reduce predation of sauger on young catfish.

Pool 19 historically has been the top producer of good quality commercial channel catfish among the 25 pools comprising the Upper Mississippi River. During the 12-year period 1953-1964, the average annual catch of channel catfish in Pool 19 was 326,745 pounds (Nord, 1967: 174). Nord (1967: 159) felt that the fishing effort, in terms of number of fishermen, was quite constant during this period, and that the commercial fishery on the Upper Mississippi River as a whole was fairly stable between 1944 and 1964.

Nord (1967: 180) reported that the total commercial catch of all species of fish in Pool 19 was 12,796,216 pounds for the 12-year period 1953-1964, and that Pool 19 ranked third among all pools on the Upper Mississippi. According to a letter from William E. Mahn, Assistant

Regional Director--Environment, U.S. Fish and Wildlife Service (April 19, 1976: 3-4), Pool 19 ranked second among all pools in total pounds of commercial fish harvested during the more recent period 1965-1974. Mr. Mahn points out that in the period 1953-1964, there were 7 years in which the catch in Pool 19 exceeded one million pounds, but that the catch never exceeded one million pounds during the period 1965-1974. There must have been a general decline in the catch on all the pools of the Upper Mississippi because the catch on Pool 19 has apparently declined, but Pool 19 has increased its relative standing among all pools from third in 1953-1964 to second in 1965-1974. Mahn (letter of April 19, 1976: 3-4) reported that when commercial fish production was expressed on a pounds per acre basis, the relative ranking of Pool 19 among all pools changed from fourth during 1953-1964 to twelfth during 1965-1974. Moreover, the commercial catch of channel catfish is apparently declining (Mahn, April 19: 4). Until additional data is made available, it is difficult to ascertain whether the decline in channel catfish harvest and decline in production of fish per acre is due to a decline in fish populations, a decline in fishing effort, or a change in the gathering and reporting of fishery statistics.

II. BENEFICIAL AND DETRIMENTAL BIOLOGICAL IMPACTS OF PROJECT ALTERNATIVES

In order to evaluate project alternatives, it is necessary first to evaluate: (1) the risk of flooding of Green Bay Levee District under existing conditions, (2) the biological damage which might occur if the FirstMiss fertilizer plant were flooded, and (3) the biological damage which might result from dredging of the main channel for sand to be used in building up the levee.

Risk of Flooding

Although the Green Bay Levee was designed to withstand a 50-year flood, the Rock Island District Corps of Engineers currently estimates that it only has the capacity to withstand a 25-year flood (U.S. Army Corps of Engineers, 1975: 2). The downward revision in levee capacity is evidently the result of using a newer and more accurate method of computing flood stage frequencies (U.S. Army Corps of Engineers, 1975: 45). There is also the possibility that a given discharge on the upper Mississippi River now produces greater flood heights than in the past. Belt (1975) provides evidence that flood heights on the Mississippi between Chain of Rocks and Chester, Illinois have increased significantly due to the combination of channel constriction by navigation works and floodplain constriction due to levees.

Whatever the reason, it does appear that there is a considerable risk of flooding in the Green Bay Levee District. The 1973 flood exceeded

the design stage of the present levee by one foot (letter from Lieutenant-Colonel Dougherty, October 18, 1976) and only intensive flood fighting efforts prevented a break. Unfavorable winds and wave action could have breached the levee in 1973. Belt (1975: 681) received a personal communication from L.B. Leopold that the 1973 flood at St. Louis probably has a recurrence interval of 30 years. The effect, if any, of the Green Bay Levee improvement on downstream flooding should be evaluated.

FirstMiss Fertilizer Plant

According to information supplied to the Rock Island District Corps of Engineers by FirstMiss, Inc., the plant would have the following amounts of materials on hand during the month of May:

2.721552×10^7 kilograms (30,000 tons) anhydrous ammonia

2.721552×10^7 kilograms (30,000 tons) diammonium phosphate

1.179339×10^6 kilograms (1300 tons) phosphoric acid (100% acid)

3.084443×10^6 kilograms (3400 tons) sulfuric acid

55,000 barrels of fuel oil

small quantities of water treating chemicals, paints, solvents, etc.

According to company spokesmen the amount of material on hand in May is actually lower than it is in April and June. Flooding is most likely to occur in the spring. According the Rock Island District Corps of Engineers the discharge at Green Bay for various flood stages is as follows:

50-year flood -- 1.019241×10^7 liters/second (360,000 cubic feet/second)

100-year flood -- 1.132490×10^7 liters/second (400,000 cubic feet/second)

200-year flood -- 1.259896×10^7 liters/second (445,000 cubic feet/second)

Assuming that the levee broke and the entire stockpile of materials dissolved in the entire flow of the Mississippi at a constant rate over a one-hour period the concentration of un-ionized ammonia in the river would be 10.1, 9.0, and 8.1 milligrams/liter for the 50-year, 100-year, and 200-year floods, respectively (Table 7). The above calculations also assume that volatile materials like ammonia completely dissolve in the water rather than escaping to the air.

Assuming the company could obtain all the railroad cars it needed, company spokesmen estimate that 2.267960-2.2721552 x 10^6 kilograms (2500-3000 tons) of materials could be moved out of the Levee District per day. It would take 25-30 days to remove the entire stockpile of materials, but presumably the most toxic ones would be moved out first. Since the peak demand for fertilizer by farmers occurs in the spring, it is unlikely that the plant would shut down and remove their stockpile unless a flood was imminent. Assuming the company had a five-day warning of a flood crest that would overtop the levee, and further assuming that they would remove the most toxic materials first, the stockpile of anhydrous ammonia would be reduced from 2.721552 x 10^7 kilograms (30,000 tons) to 1.360776 x 10^7 kilograms (15,000 tons), and all other materials would remain as above.

Using the same assumptions as above, this amount of material would result in the following concentration of un-ionized ammonia in the river: 5.6, 5.0, and 4.5 milligrams/liter for the 50-year, 100-year, and 200-year floods respectively (Table 7).

Ammonia is a fast-acting toxicant. It is the un-ionized form, NH_3, which is toxic, rather than the total ammonia concentration. The amount of ammonia available in the un-ionized form depends on the pH, temperature,

Table 7

Estimated Concentrations of Un-ionized Ammonia, NH_3 (u), Which Might Occur Downstream from the FirstMiss Inc. Fertilizer Plant for a Period of One Hour Following Flooding of the Plant*

	50-year Flood	100-Year Flood	200-Year Flood
Assuming the entire stockpile of anhydrous ammonia and diammonium phosphate was on hand when the levee broke			
Total NH_3 mg/l	838	754	677
NH_3(u) mg/l**	10.1	9.0	8.1
Assuming that warning of the flood was received 5 days prior to breaking of the levee and 15,000 tons of anhydrous NH_3 was removed from the plant site			
Total NH_3 mg/l	467	420	377
NH_3(u) mg/l**	5.6	5.0	4.5

*Assuming that all the anhydrous ammonia and diammonium phosphate enters the entire volume of water flowing in the Mississippi at Green Bay over a period of one hour. Information on the discharge at Green Bay during 50-, 100- and 200-year floods was obtained from the Rock Island District Corps of Engineers (telephone conversation of January 19). Information on the stockpile of materials and the capability for removing the stockpile to high ground was provided by the manager of the FirstMiss Inc. plant to Mr. Bill Davis, Rock Island District Corps of Engineers, who relayed the information to the writer in a telephone conversation on January 17.

**Assuming a water temperature of 18° C, a pH of 7.6, and a total dissolved solids concentration of 500 mg/l, values which are characteristic of May values for Pool 19. NH_3(u) levels would be 1.2% of the total NH_3 (Skarheim, 1973: 9).

and total dissolved solids (TDS) concentration of the water (Skarheim, 1973: 1-2). At the prevailing pH (7.6), TDS (500 milligrams/liter), and temperature (18° C) of the Mississippi River in the spring, approximately 1.2% of the ammonia would exist in the un-ionized form (Skarheim, 1973: 9). Without some additional experimental data, it is difficult to know what effect the acid stored at the FirstMiss plant would have on the pH of the water. If the acid appreciably lowers the pH of a portion of the Mississippi River, then less un-ionized ammonia would be available. It is also difficult to know exactly how the breaks in the levee might occur. Presumably a break would occur at one point and water would spill into the District. The toxic materials would be in contact with a certain volume of water for a certain period of time. Some of the toxic materials, such as the volatile ammonia, might escape to the air. The river might break through the levee at more than one point and flow across the plant site. Even if there was only one break in the levee, when the flood crest subsided, the toxicant-laden water would begin to move out into the Pool.

The computed toxicant concentrations given above would be sufficient to destroy aquatic life wherever such concentrations occurred. Laboratory experiments have shown that when bluegill, channel catfish, and fathead minnows are exposed to un-ionized ammonia concentrations of 2-4 milligrams/liter, mortality begins within 30 minutes, and 50% of the organisms exposed are killed within 8 hours (Illinois Natural History Survey, unpublished data). Un-ionized ammonia concentrations of 2 milligrams/liter cause mortality of Asiatic clams and fingernail clams while concentrations

as low as 0.04 milligrams/liter inhibit the cilia on the gills of adult fingernail clams (Illinois Natural History Survey, unpublished data).

On the basis of the admittedly crude estimates given above, for one toxicant (un-ionized ammonia), I conclude that flooding of the FirstMiss fertilizer plant would present a considerable hazard to the benthic organisms, fish, and wildlife of Pool 19.

Effects of Dredging in the Main Channel

In 1966 and 1967, 1,850,000 cubic yards of sand was dredged from the Mississippi River between mile 386 and mile 393 for fill for an industrial site within the Green Bay Levee which was later to become the FirstMiss fertilizer plant (dredging plan, prior to 1966; An analysis of biological conditions in the main channel of Pool 19, sometime after April 19, 1976. 4). An additional 650,000 cubic yards was dredged for the purpose of providing a docking area. The plan shows that dredging could have occurred anywhere between the two mileages given above and anywhere in the main channel of the river except within 300 feet of the levee or 150 feet of the bank line. At the same time this dredging was going on, Thompson (1973) was carrying out field studies of duck concentrations and movements on the Keokuk Pool. Thompson's field studies extended from the fall of 1966 through the spring of 1968 (Thompson, 1973: 369). Aerial observations by Dr. Frank C. Bellrose of the Natural History Survey and ground observations by Thompson showed that there were three diving duck concentration areas within the area where dredging was permitted. Thompson referred to these areas as U1, U2 and U3 (Thompson, 1973). Thornburg (1973: 382)

studied duck populations and movements in the fall of 1969, and also found three diving duck concentration areas in the upper part of Pool 19, two of which were within the area where dredging was permitted in 1966-1967, and one of which was downstream from the site of dredging. Although Thornburg did not make any night observations of the ducks, he did observe that the ducks move from the lower portions of Keokuk Pool to a destination somewhere in the upper or middle section, where they presumably engage in feeding activities at night (Thornburg, 1973: 384).

Our own studies show that rafts of diving ducks consistently occur over fingernail clam beds. Therefore Thompson's and Thornburg's areas U1, U2, and U3 most probably indicate areas where there was a rich bottom fauna. Although I do not know the exact areas where dredging occurred, the fact that there were diving duck concentrations and presumably fingernail clam beds within the area where dredging was permitted indicates that there were no widespread deleterious effects on diving duck utilization or benthic food resources resulting from the dredging of 2.5 million cubic yards of sand in the same general area, although organisms that were physically removed by dredging and deposited behind the levee were obviously destroyed.

Therefore I believe that dredging a lesser amount of sand for improvement of Green Bay Levee, using essentially the same techniques that were used for raising the site of the fertilizer plant, will also have a minimal impact on the areas which are not actually dredged. Since the dredged material will be deposited on the inside of the existing levee, the return water and sediment must pass through the drainage system of the Levee District before it is pumped out into the Mississippi River. This procedure will reduce the amount of suspended sediment which might

otherwise blanket the bottom. Since the larger sediment particles will be trapped within the Levee District, only the finer ones will be returned to the River and the river current may be sufficient to prevent blanketing of the bottom in the vicinity of the pumping plant. Samples of bottom materials in the area to be dredged should be tested for leaching of toxic materials in the laboratory to determine whether return flows from the Levee District will contain excessive amounts of toxic material. An analysis of bottom material from an area above the proposed project site at mile 400.1 (U.S. Army Corps of Engineers, 1975: D-1) showed that the muds there did not exceed the USEPA standards for sediments.

Since organisms which are removed by the dredge and deposited in the Levee District will be destroyed, it is important to know whether significant populations of benthic organisms exist within the channel between miles 386 and 390 where dredging is to occur. The only sampling of this area has been conducted by the Ecological Services Office of the U.S. Fish and Wildlife Service, Rock Island (Results of benthic sampling, February 24-25, 1976). They conducted biological sampling between miles 386 and 391 on February 24 and 25, 1976. Personnel from the U.S. Fish and Wildlife Service frequently took several samples on a transect at a given river mile location. Six of 13 samples were described as having common to abundant populations of organisms. Six out of 7 river mile locations contained sparse to abundant populations of benthic organisms. Seven of 13 stations were characterized as being unproductive areas or as having sparse populations, and only one location of 7 was described as having sparse populations of all groups of benthic organisms. The U.S. Fish and Wildlife Service did not supply quantitative data, so it is difficult to know whether a sample characterized as "abundant" would be comparable to a sample taken in some of

the most productive areas of the Pool, such as Station 4 of the Illinois Natural History Survey. Once again, the fact that the U.S. Fish and Wildlife Service found some areas where benthic organisms were abundant indicates that the 1966-67 dredging either did not have widespread effects, or that recovery of some components of the benthic fauna occurs within 10 years.

Ecologists are fond of using the term "resilience" when talking about the capacity of an ecosystem to resist stress. The term is based on an example from physics. A spring is said to be resilient. If the spring is subjected to a stress, it will stretch. When the stress is removed, the spring returns to its former shape and size. However, if too great a stress is applied to the spring, the spring is permanently deformed, and does not return to its normal condition when the stress is removed. The Illinois River is an example of an aquatic ecosystem which has been deformed even though four billion dollars has been spent on waste treatment in the Illinois valley (Briceland, 1976: 5). Even though oxygen levels during a low-flow period such as occurred in the summer of 1976 are at the highest levels they have been almost since the turn of the century, the Illinois River has not recovered its bottom fauna, fish or wildlife.

It is easy to say that an ecosystem is resilient to stress; it is difficult to determine precisely how much stress can be applied before the resiliency is exceeded and permanent deformation occurs. Different species within the ecosystem have different capabilities for avoiding, resisting, or recovering from stress. Motile organisms such as fish can sense and avoid toxic materials such as chloramines. Some species of aquatic insects drift, that is, they swim out of the mud into the water,

where the current can carry them downstream. This response may be triggered by a noxious substance; at other times drifting appears to be a way of colonizing downstream areas. Many aquatic insects have aerial adult stages so fertilized females can fly or be blown considerable distances before they deposit their eggs. Mussels may be the most sensitive to dredging, and the slowest group of organisms to recolonize ~~in the~~ an area. Ellis (1936: 39-40) showed that mussels which were adapted to living in sand or gravel died after becoming covered with ¼ to 1 inch of sediment, while mussels suspended in cages above the sediment survived. Dead mussels had their gills clogged with sediment particles. Imlay (1972) reported that some species of mussels are much more sensitive to displacement than others.

The Petersen dredge used by the U.S. Fish and Wildlife Service does not adequately sample mussel populations. A crowfoot bar should be used to determine whether any mussel beds exist in the area which is to be dredged. Such a survey would also indicate whether there are any rare or endangered species of mussels in the area. Dredging should not be done in areas where mussel beds occur.

Different life history stages of the same species may also show different susceptibility to stress. For example, we have found that adult fingernail clams (*Musculium transversum*) are more sensitive to handling than juveniles. We have also found that a potassium concentration of 39 milligrams/liter severely inhibits the cilia on the gills of large fingernail clams, while small clams can tolerate this amount. Rogers (1976: 4, 5, 7) showed that when adult fingernail clams (*Musculium transversum*) were covered by 2.7 to 15.8 centimeters of sediment for 7 days, 54-91% of the adults died while 63-71% of the juveniles remained alive.

The significance of these findings is that adult fingernail clams can tolerate less blanketing by sediment than the juveniles. Blanketing by sediment from dredging itself or by return flows from the pumping plant could be detrimental to certain mussels and to fingernail clams. It should be possible to dredge far enough away from mussel or fingernail clam beds, so that blanketing would not occur.

Project Alternatives

Only those alternatives which have been proposed and discussed by proponents and opponents of the Green Bay Levee Project will be discussed here. Alternatives which are not discussed here, such as floodplain evacuation, floodproofing, and construction of upstream flood storage reservoirs, are adequately treated in the Revised Draft Environmental Statement (1975: 32-34).

No Project

Some persons and organizations are opposed to any levee improvement project for the Green Bay District (for an example see the letter from Mr. James A. Settles, President of the Iowa Wildlife Federation, March 15, 1976). As indicated above, flooding of the FirstMiss fertilizer plant could destroy benthic organisms and fish over a substantial portion of Keokuk Pool. The damage might even extend downstream of Pool 19. For this reason, most of the State and Federal natural resource organizations favor an alternative to the project proposed by the Rock Island District Corps of Engineers, rather than no project at all. One may question the wisdom of the initial decision to build a fertilizer plant which stockpiles toxic materials within a levee district that at the time was known to provide only

50-year flood protection. However, the fact is that the plant is presently located in the Levee District, which is now known to have only 25-year flood protection, and that flooding of the plant represents a major threat to the ecosystem of Pool 19. Widespread destruction of the benthic organisms in Pool 19 and perhaps further downstream would have a detrimental impact on diving ducks in the Mississippi Flyway. For the sake of protecting Keokuk Pool, which is a uniquely valuable resource, a very high level of protection, such as 200-year flood protection, is desirable.

<u>200-Year Protection, With Levee Material Dredged from Main Channel</u>

This alternative has the most favorable benefit:cost ratio and is the one favored by the Green Bay Levee District and the Rock Island District U.S. Army Corps of Engineers. The major disadvantages of this alternative are that material would have to be dredged from the main channel to raise the main stem levee, and that increased flood protection might encourage industrial development within the Levee District. Increased industrial development might increase the amount of waste effluent discharged to Keokuk Pool, increase the risk of toxic spills, and make it more difficult to maintain portions of the shoreline in an undeveloped state, due to rising land prices.

However, industrial development of Green Bay District is not inevitable. Under Iowa law, land is taxed according to use, rather than according to value (Environmental Coordination Meeting, August 26, 1976: 14). Therefore farmers in the Green Bay Levee District are unlikely to be forced out of business due to high taxes which are based on the value of land for commercial or housing development. The Green Bay District has prevented housing developments within the District in the past by informing potential developers that no occupants of housing developments would be

allowed to cross the District levees (letter from the Green Bay trustees to U.S. Corps of Engineers, Sept. 8, 1976). According to the Green Bay District trustees, the attorney for the District cooperated with the Iowa Conservation Commission and the Iowa Natural Resources Council in writing and securing passage of a law in 1962 which has been used to restrict construction or eliminate unsightly construction between the Mississippi River and the Green Bay Levee.

However, the fact remains that the District did allow an industrial plant to move into the District in 1966, and that Lee County, Iowa has no zoning ordinance or land use plan (Revised Draft Environmental Statement, 1975: 19). Apparently, individual land owners within the Green Bay Levee District could sell their land for industrial development.

The most rational solution to this problem of land use would be for the states of Illinois and Iowa to develop a comprehensive management plan for Pool 19. Some areas of the Pool should probably be set aside as a National Wildlife Refuge, some areas should be public hunting and shooting areas, and others could be slated for industrial development. Creation of a refuge or public use area within Keokuk Pool should not be as difficult as it is in some parts of the country, because substantial tracts of the shoreline, the islands, and the bottom are owned by one entity, the Union Electric Company. Under the present system, every proposal for development, dredging, or filling probably will be opposed by the State and Federal natural resources agencies, who are justifiably concerned with conserving the valuable natural resource represented by Pool 19. Once a comprehensive land and water use plan were adopted, development in specified areas could presumably proceed with a minimum of conflict.

As mentioned above, I believe that dredging of the main channel could be done in such a way that there would be no detrimental impact on the productivity of Pool 19 or on the utilization of Pool 19 by diving ducks.

<u>200-Year Protection for Fertilizer Plant, 50-Year Protection for the District, With All Material for the Levee to Come from Land Sites</u>

The advantage of this plan is that it would protect Pool 19 from the flooding of the fertilizer plant while at the same time not encouraging further industrial development of the Green Bay Levee District. This is the plan favored by the State and Federal natural resource agencies. The primary disadvantage of the plan is that the Corps of Engineers may be legally prohibited from constructing a levee which has only one beneficiary, and the fertilizer plant may be unable or unwilling either to construct a levee with its own funds or to move out of the District if the levee is not improved. The legal issue needs to be clarified: instead of regarding the ring levee as protecting the fertilizer plant from flooding, the levee could be regarded as protecting Pool 19 from flooding of the fertilizer plant. Even if the cost:benefit ratio were less than 1.0, the project might still be justified if it makes a positive contribution to environmental quality such as preserving or maintaining significant natural environmental attributes of an area (Memorandum for record, May 19, 1976: 8-9).

There are other disadvantages. The ring levee would encroach upon Green Bay Lake, which is used by waterfowl, or on an evaporation and settling pond which enables the fertilizer plant to achieve a zero water discharge for all process and sanitary waters (letter from Mr. Cecil Alvarez, Plant Manager, FirstMiss Inc., Sept. 10, 1976: 2). Recycling

all waste within the plant is a commendable waste treatment program which protects Pool 19. Clay would have to be obtained from an additional 85 acres of land, and be placed on the outside of the main stem levee, thereby occupying an additional 27 acres beyond the existing levee. Apparently there is some risk that archaeological sites might be disturbed. Until the clay material could be top-dressed and seeded, there is a chance that rainfall running off the new material might carry sediment into areas of the river adjacent to the levee.

Finally, if the cost of the ring levee around the fertilizer plant plus 50-year protection for the remainder of the District is approximately equal to the cost of providing 200-year protection for the entire District, it would seem reasonable to choose the latter alternative. Mr. Cecil Alvarez, Plant Manager for FirstMiss Inc., points out that most of the ring levee would be new levee and would require 2.8 times as much fill as raising an equivalent length of the existing levee (letter of Sept. 10, 1976: 2).

<u>100-Year Flood Protection for the District, With All Material to Come from Land Sites</u>

The disadvantages of using clay fill from land sites are described above. From the standpoint of protecting the Pool from flooding of the fertilizer plant, it would be better to have 200-year protection, rather than 100-year protection. I am not aware of any studies of the probable productive life of Keokuk Pool. The productive life depends on such factors as the rate of sedimentation in the Pool, and the useful life of Dam 19 before it needs replacement. If the rate of sedimentation in the Pool is very low, and Dam 19 is replaced when necessary in the future, the productive life of the Pool could be on the order of several hundred years, in which case 200-year flood protection would be more desirable than 100-year flood protection.

III. CONCLUSIONS

1. Pool 19 receives about 20 million diving duck-days of use per year, and has therefore been characterized as the most important inland body of water for diving ducks in North America. Utilization of the Pool by diving ducks and the high production of commercial fish is directly attributable to the unusual abundance of benthic food organisms. The biomass of benthic food organisms in some areas of Pool 19 is as high as 8,000 kilograms/hectare (7,137 pounds/acre), and the number of individual organisms is as high as 100,000 per square meter.

2. The dredging of 2,500,000 cubic yards of sand from the reach of the Mississippi River bordering the Green Bay Levee District in 1966 and 1967 apparently had no widespread effect on diving duck utilization of this reach of the river. Between the fall of 1966 and the spring of 1968, Thompson (1973: 368) found three diving duck concentration areas within the reach of the river where dredging was permitted, and in the fall of 1969 Thornburg (1973: 382) reported two diving duck concentrations within this reach and one downstream from this reach. Therefore it is reasonable to expect that the dredging of 840,000 cubic yards of bottom material from the main channel of the Mississippi River bordering the Green Bay Levee District will have little effect on the food resources of Keokuk Pool and hence on the diving duck utilization of the Pool, provided that dredging is not done in portions of the channel where dense populations of food organisms or mussels occur or at times when diving ducks are utilizing the Pool.

The following criterion is proposed for determining which areas should or should not be dredged: if mussel beds are present, or the combined biomass of mayflies, midges, snails, and fingernail clams exceeds 10 kilograms/hectare during the summer months, the area should not be dredged. This criterion is based on the fact that in portions of the Illinois River where the combined biomass of these four groups of organisms is below 10 kilograms/hectare, the condition factor of the bottom-feeding fish is poor and there is little utilization of the river by diving ducks. Dredging should occur far enough away from the productive areas so that sediment disturbed by the dredging does not blanket these areas.

3. Flooding of the FirstMiss fertilizer plant would probably result in widespread destruction of much of the aquatic life in Pool 19, and perhaps in areas downstream from Pool 19. A high level of flood protection for the fertilizer plant is justified in order to protect the unique natural resource represented by Pool 19. The purpose of protecting the Pool would be thwarted if the higher level of protection results in unregulated industrial and urban development along the shoreline of Keokuk Pool, since such development would increase the threat of chronic pollution, accidental spills, increased traffic, and increased demand for dredging of harbor sites and access channels. It would be desirable for the states and counties bordering Pool 19 to develop a comprehensive management plan for the Pool and adjacent land areas. The plan could include a wildlife refuge, public hunting and shooting areas, and perhaps areas zoned for industrial and urban development. In the absence of such a coordinated plan, it would be desirable for Lee County to have a comprehensive plan, since the Green Bay Levee District is in Lee County. Even in the absence of such comprehensive land use plans, 200-year flood protection for the entire District is justified for the following reasons:

A. The District has had a history of rejecting housing developments within the District.

B. The FirstMiss fertilizer plant has achieved zero discharge of waste, which protects the Pool. Construction of a ring levee would apparently interfere with waste treatment.

C. Land in Iowa is taxed according to use rather than value, so the farmers in the District would not be forced to sell their land to developers as a result of increased land values and taxes resulting from levee improvement. The fact remains that an improved levee would make the District more attractive for industrial development, and individual land owners might be tempted to sell their land.

D. If the cost of putting a ring levee around the fertilizer plant and providing 50-year protection for the rest of the District is approximately equal to the cost of providing 200-year flood protection for the entire District, then it would seem reasonable to choose the latter alternative.

E. If the ring levee is rejected for economic and legal reasons, and 200-year flood protection for the entire levee is rejected for environmental reasons, then the natural resource represented by Pool 19 will receive a lesser degree of protection from flooding of the FirstMiss fertilizer plant.

IV. RECOMMENDED ADDITIONAL SCIENTIFIC STUDIES

Evaluation of Hazard to Pool 19 in the Event of Flooding of the FirstMiss Inc. Fertilizer Plant

It would be desirable for the FirstMiss fertilizer plant to provide additional chemical data, such as the probable effects of their acid stores on the pH of the river, in the event of flooding. They could provide information on how much diammonium phosphate and ammonia might exist in the form of un-ionized ammonia, and whether any of this material would be bound to sediment particles thus leaving some residual toxicity in the Pool after flooding. It is also necessary to know how much gypsum and potassium-containing material is stored at the plant. The plant could also provide bioassay data on the effects of their products and waste on representative Pool organisms.

Studies Prior to Dredging

Sediment samples in the area to be dredged should be chemically analyzed to determine whether or not the sediments meet USEPA and State EPA standards for dredged sediment. Leaching studies should be done to determine whether toxic materials will be released from sediment in the return flows to the river. A biological inventory should be made of the area to be dredged. Dredging should not be done in areas where there are

mussel beds, or where the total biomass of midges, mayflies, snails, and fingernail clams exceeds 10 kilograms/hectare during the summer months, nor should dredging occur in such close proximity to these areas that blanketing by sediment will occur. Dredging should not be done during the spring waterfowl migration, when food resources of the pool are at low ebb and the diving ducks utilize the upper part of Pool 19 to a greater extent than they do during the fall. Dredging should be restricted during the fall to areas where diving ducks do not concentrate.

Studies During Dredging

Representatives of the Federal and State conservation ~~areas~~ agencies should be invited to observe the dredging to ascertain that the dredging is actually done in the areas prescribed above. Water quality and the amount of re-suspended and redeposited sediment from the dredging itself and from the return flows should be monitored. Diving duck utilization of the Pool should be monitored.

Post-dredging Studies

The biological recovery, if any, of the areas which have been dredged should be determined by repeated sampling of the same areas. Adjacent areas should also be sampled to determine if there were indirect effects of dredging, and areas remote from the dredging should be sampled as a reference area to account for Pool-wide changes in the benthic fauna.

SOURCES

Reports, Statements, Letters, Telephone Calls and Memoranda

Date illegible, sometime prior to 1966. Plan showing location and extent of dredging for sand fill and for a dock facility for Sinclair Petrochemicals Inc. in Green Bay Levee District.

November, 1975. Revised draft environmental statement. Green Bay Levee and Drainage District No. 2, Iowa. Local flood protection, Mississippi River.

January 12, 1976. Letter from Madonna V. Leffler, Krebill Engineering Company, to Mr. Walter Caldwell, President of Iowa Gateway, Inc., giving the exact acreage to be filled at the proposed construction site at mile 371.1 on Pool 19.

January 19, 1976. Letter from Colonel Daniel L. Lycan, District Engineer, to Mr. Jerome Svore, Regional Administrator, Region VII, U.S. Environmental Protection Agency, requesting comments on the Iowa Conservation Commission's recommendations.

January 23, 1976. Letter from Mr. Dale O. Vandenburg, Staff Director, Environmental Quality Evaluation, Northeastern Area, U.S. Forest Service, to Colonel Daniel L. Lycan, District Engineer, stating that Forest Service Comments on the Draft Environmental Statement have been satisfactorily addressed in the January 19, 1976 letter from Colonel Lycan.

Undated, sometime after January, 1976. Case study -- Green Bay Levee and Drainage District. An analysis of the conflict between the Rock Island District, Corps of Engineers and the state and federal conservation agencies.

February 9, 1976. Letter from Mr. Edwin V. Weiss, Chief of Planning Division, U.S. Army Corps of Engineers, to District Engineer, Rock Island District, requesting the Rock Island District to make additional efforts to resolve the issue of dredging for levee material.

February 24-25, 1976. Results of benthic sampling conducted by USFWS staff members Mr. Dave Parsons, Mr. Ed Perry, and Mr. Al Mueller, and by Mr. Steve Walters from the Iowa Conservation Commission.

March 2, 1976. Disposition by Mr. Frank W.Collins, Chief, Environmental Resources Section, Rock Island District, U.S. Army Corps of Engineers, describing the coordination meeting with state and federal fisheries and wildlife biologists on February 26, 1976 in the Rock Island Office of the Fish and Wildlife Service.

March 15, 1976. Letter from Mr. James A. Settles, President, Iowa Wildlife Federation, to Colonel Daniel Lycan, District Engineer, urging the Corps to discontinue plans for the project.

March 18, 1976. Letter from Anthony T. Dean, Director, Illinois Department of Conservation, to Colonel Daniel L. Lycan, District Engineer, supporting 50-year flood protection for agricultural areas and 200-year flood protection for the fertilizer plant with all levee material to come from the land.

April 5, 1976. Biological assessment of Iowa Gateway Terminal proposed construction site, by Mr. Fred Karre, Southeastern Community College.

April 7, 1976. Letter from Mr. Jerome H. Svore, Regional Administrator, Region VII of the U.S. Environmental Protection Agency, to Colonel Daniel L. Lycan, District Engineer, recommending 50-year flood protection for the agricultural area, a higher level of flood protection for the fertilizer plant, and exclusive use of clay from on-land borrow areas.

April 13, 1976. Letter from Mr. Fred A. Priewert, Director, Iowa Conservation Commission, to Colonel Daniel L. Lycan, District Engineer, favoring a ring levee for the fertilizer plant and a lesser degree of flood protection for the agricultural areas, with all levee material to come from the land.

April 19, 1976. Letter from Mr. William Mahn, Assistant Regional Director, Environment, North Central Region, U.S. Fish and Wildlife Service, to Colonel Daniel L. Lycan, District Engineer, Rock Island District, U.S. Army Corps of Engineers, outlining USFWS position on the Green Bay Levee project.

Undated, sometime after April 19, 1976. An analysis of biological conditions in the main channel of Pool 19. (A response to the April 19, 1976 letter form Mr. William Mahn.)

April 23, 1976. Letter from Mr. Walter E. Caldwell, President of Iowa Gateway, Inc., to Mr. James A. Settles, President of the Iowa Wildlife Federation, discussing concerns expressed by the Iowa Wildlife Federation over filling of 42.76 acres of Pool 19 at mile 371.1.

May 19, 1976. Memorandum for record prepared by Mr. Marvin Williams, study manager: documentation of Rock Island District efforts to resolve environmental conflicts.

May 24, 1976. Letter from Mr. Walter E. Caldwell, President of Iowa Gateway, Inc., to Colonel Daniel L. Lycan, District Engineer, discussing environmental impacts of filling 42.76 acres of Pool 19 at mile 371.1 for a coal handling facility.

June 1-10, 1976. Telephone conversations between Mr. Frank Collins, RID, and the following individuals: Dr. Ed Crowley, Loras College; Mr. Jeff Johnson, U.S. Army Corps of Engineers Waterways Experiment Station; Dr. Hugh Ferguson, Southeastern Community College; Dr. Fred Karre, Southeastern Community College; Dr. Richard Sparks, Illinois Natural History Survey.

June 7, 1976. Letter from Colonel Daniel L. Lycan, District Engineer, to Mr. Charles A. Hughlett, U.S. Fish and Wildlife Service, and to Mr. Robert J. Koke, Cheif of Region VII of the U.S. Environmental Protection Agency, requesting a review of Iowa Gateway's biological assessment of the effects of filling 42.76 acres of Pool 19 at mile 371.1.

June 16, 1976. Letter from Mr. Edward M. Brigham III, North Midwest Representative, National Audubon Society, to Colonel Daniel L. Lycan, District Engineer, opposing 200-year flood protection for the Green Bay District and the dredging of sand from the Mississippi River.

June 25, 1976. Telephone conversation between Mr. William Davis, Rock Island District, Corps of Engineers, and Mr. Tim Kubiak, U.S. Environmental Protection Agency, Kansas City, regarding toxic chemicals at FirstMiss fertilizer plant which might enter Keokuk Pool during a flood.

July 21. 1976. Disposition by Mr. Frank Collins, Rock Island District, Corps of Engineers, describing coordination meeting with U.S. Fish and Wildlife Service on July 20, 1976.

August 12, 1976. Letter from Colonel Daniel L. Lycan, District Engineer, Rock Island District, U.S. Army Corps of Engineers, to persons and agencies interested in the proposed Green Bay Levee project, announcing a meeting on August 26, 1976 at Wever, Iowa to discuss alternative plans for flood damage reduction.

August 26, 1976. Statement prepared by Rock Island District for the Environmental Coordination Meeting, Wever, Iowa, on August 26, 1976, describing project alternatives.

September 8, 1976. Letter from Mr. Henry J. Pieper, Mr. James Carney, and Mr. Richard Mabeus, Trustees of the Green Bay Levee and Drainage District, to U.S. Corps of Engineers, Rock Island, favoring 200-year flood protection using sand dredged from the Mississippi.

September 9, 1976. Letter from Mr. and Mrs. Harold J. Bonar, Wever, Iowa, to Colonel Daniel L. Lycan, District Engineer, favoring 200-year flood protection using sand dredged from the Mississippi.

September 10, 1976. Letter from Mr. Cecil Alvarez, Plant Manager, FirstMiss Inc., to U.S. Corps of Engineers, Rock Island, favoring 200-year flood protection with the mainstem levee built up with sand dredged from the Mississippi River.

September 10, 1976. Letter from Edson P. Cornick, Manager, Green Bay Grain Company, to U.S. Corps of Engineers, Rock Island, favoring alternative no. 3 presented at the August 26 meeting in Wever, Iowa.

September 11, 1976. Letter from Mr. A.B. Carlson, Vice President of KEEP (Keep Earth's Environment Pure), to U.S. Army Corps of Engineers, Rock Island District, opposing the project.

September 13, 1976. Letter from Mr. E.A. Hicklin of Hicklin and Matthews Law Offices to Colonel Daniel L. Lycan, District Engineer, setting forth the position of the trustees of the Green Bay Levee and Drainage District.

September 13, 1976. Letter from Mr. Fred A. Priewert, Director, Iowa Conservation Commission, to Colonel Daniel L. Lycan, District Engineer, opposing the project as proposed.

September 14, 1976. Letter from Mr. W.H. Klingner, President, Upper Mississippi Flood Control Association, to Colonel Daniel L. Lycan, District Engineer, favoring a combination of earth fill and dredging to raise Green Bay Levee.

September 15, 1976. Letter from Mr. C.E. Richards, Jr., President, Fort Madison Industrial Development Committee, to U.S. Corps of Engineers, Rock Island, favoring a sand levee providing 200-year flood protection.

September 20, 1976. Letter from John McGuire, Director, Illinois Department of Conservation, to Colonel Daniel L. Lycan, District Engineer, supporting improvement of the Green Bay Levee to provide 100-year flood protection with clay material from land borrow sites.

September 24, 1976. Report of environmental coordination meeting, held at Wever, Iowa on August 26, 1976.

September 27, 1976. Letter from Mr. William Mahn, Assistant Regional Director -- Environment, North Central Region, U.S. Fish and Wildlife Service, to Colonel Daniel L. Lycan, District Engineer, recommending that all borrow materials be obtained within the levee district, that a ring levee providing 200-year flood protection be placed around the fertilizer plant, and that the remainder of the levees provide 50-year protection.

September 28, 1976. Letter from Mr. William G. Gordon, Regional Director, National Marine Fisheries Service, U.S. Department of Commerce, to Colonel Daniel L. Lycan, District Engineer, supporting use of an upland clay borrow site rather than dredging to obtain material for raising Green Bay Levee.

October 19, 1976. Letter from Lieutenant Colonel George J. Dougherty, Deputy District Engineer, Rock Island District, to Mr. Fred A. Priewert, Director of the Iowa Conservation Commission, discussing the level of protection for the Green Bay District and regulation of land use.

January 17, 1977. Telephone conversation between Dr. Richard E. Sparks, Illinois Natural History Survey, and Mr. William L. Davis, Rock Island District, Corps of Engineers, regarding inventory of toxic materials at FirstMiss fertilizer plant.

January 19, 1977. Telephone conversation between Dr. Richard E. Sparks, Illinois Natural History Survey, and Mr. William L. Davis and Mr. Frank Collins, Rock Island District, U.S. Army Corps of Engineers, regarding (1) discharge at Green Bay during flooding, (2) ownership of lands in Keokuk Pool and bordering Keokuk Pool, and (3) status of proposed barge channel to proposed Fort Madison industrial park.

January 19, 1977. Telephone conversation between Dr. Richard E. Sparks and Dr. Frank C. Bellrose of the Illinois Natural History Survey and Dr. David Trauger, Northern Prairie Wildlife Research Station, U.S. Fish and Wildlife Service, Jamestown, North Dakota, regarding data on canvasback and lesser scaup duck populations.

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